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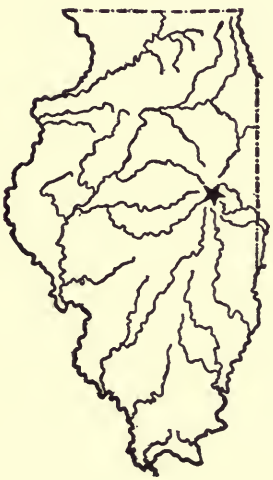
# EXPERIMENTS WITH BLISTER CANKER OF APPLE TREES

By H. W. Anderson



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# EXPERIMENTS WITH BLISTER CANKER OF APPLE TREES

By H. W. Anderson, Associate Chief in Pomological Pathology

An investigation of the life history of the fungus causing apple blister canker was initiated in 1917, but before sufficient progress had been made to warrant publication, the comprehensive investigations of Cooper[1] were published. As a result, this phase of the investigation was discontinued and stress was laid on control measures. No one had determined whether excision[2] of the cankers and removal of diseased limbs in an orchard over a period of years would successfully prolong its productive period. This phase of the subject received the major emphasis and as a result a popular circular was published in 1922,[3] giving the grower the methods employed in the investigations together with general advice on the care of the orchard to prevent infection. The purpose of the present publication is to give the data on which the former publication was based and to present additional facts resulting from a continuation of the investigations. During the eight years covered by this experiment, certain facts in regard to the etiology of the disease and the environmental factors inducing canker development were secured and will be here recorded.

## ECONOMIC IMPORTANCE OF BLISTER CANKER

The loss from blister canker consists almost entirely of the direct elimination of bearing surface, altho there is some evidence that trees in which the disease is established thruout the wood are thereby weakened and bear inferior fruit. Observations of the author have shown that diseased trees, where external cankers are not present, are equally productive with those not diseased, and it is only when a limb is almost completely girdled by a superficial canker, that the apples become inferior in quality. Wood infection in no wise stunts the growth of the tree.

Since limbs and entire trees are killed during their most productive period, it is evident that heavy losses must result when this disease is prevalent in an orchard (Fig. 1). Most of the loss in Illinois at present is confined to a few susceptible varieties, such as Ben Davis and Gano. In orchards planted to these varieties, it is estimated that

[1]Cooper, J. R. Studies of the etiology and control of blister canker on apple trees. Nebr. Agr. Exp. Sta. Res. Bul. 12. 1917.

[2]The term "excision" is used in this publication to designate the process of removing bark in the diseased area and does not imply the removal of diseased wood or the eradication of the canker.

[3]Orchard practice for the control of blister canker of apple trees. Ill. Agr. Exp. Sta. Circ. 258. 1922.

10 percent or more of the bearing wood is unproductive as a result of blister canker. Other varieties suffer no appreciable loss, altho blister canker may be found to a limited extent on most of our standard varieties. The greatest loss by far results from the early decline of Ben Davis plantings. An orchard of this variety soon becomes so badly diseased that it is no longer profitable to care for the straggling trees (Fig. 2). The average life of a Ben Davis in Illinois is about twenty-five years, while orchards planted to other varieties are at their maximum period of production at this age. Where alternate blocks of Ben Davis and other varieties are planted, the loss of the

FIG. 1.—A COMMON SIGHT AROUND AN OLD BEN DAVIS ORCHARD
All these limbs and many more were removed on account of blister canker.

trees in the Ben Davis rows is especially serious since the owner rarely replants and the orchard is retained on account of the nonsusceptible varieties, thus resulting in a waste of valuable space.

In one county during the past four years about 50,000 trees have been removed largely because of blister canker. Most of these orchards were less than thirty years old. Fifty-year-old Ben Davis trees bearing excellent crops have been observed, and there is no reason why orchards of this variety could not be producing after half a century were it not for this disease. It is rare to find a Ben Davis orchard over thirty-five years of age and if found, it is seldom profitable because of the numerous missing or crippled trees. To no other cause than blister canker can the early decline of Ben Davis orchards in this state be ascribed. Ben Davis and Gano constituted 30 percent of the bearing apple trees of Illinois in 1920. Owing to the nature of the disease, it is impossible to calculate the exact financial loss, but it is evident that it must be very great. Fortunately the younger orchards are not so heavily planted to these varieties, and the loss

will decrease after the present old orchards are moved.[1] On the other hand, new varieties of recent introduction have not been subjected to adequate tests to determine their resistance to this disease, so that there is a possibility of future heavy losses if care is not taken to follow correct cultural practices.

## HISTORY AND DISTRIBUTION

A detailed history of apple blister canker in America is given by Gloyer[2] and others and need not be repeated here except as to its

FIG. 2.—AN ADVANCED STAGE OF BLISTER CANKER

It is doubtful if a tree such as this will produce enough to justify saving it.

bearing on Illinois conditions. The disease has been known to occur on the apple since 1831, when Schweinitz first described the fungus, but it was not until 1900 that its serious nature in the Middle West was recognized. Hasselbring[3] observed the disease in Illinois orchards

[1]Ben Davis is still recommended for the river bluff sections of western Illinois (see Ill. State Hort. Soc. Trans. 62, 33. 1928), and there it is being planted by progressive fruit growers in preference to the newer varieties.

[2]Gloyer, W. O. Blister canker of apple and its control. N. Y. (Geneva) Agr. Exp. Sta. Bul. 485. 1921.

[3]Hasselbring, H. Canker of apple trees. Ill. Agr. Exp. Sta. Bul. 70. 1902.

during the summer of 1901 and first called attention to the parasitic nature of the fungus and the fact that it was the real cause of the death of many apple trees. He gave a good description of the symptoms of the disease and observed the penetration of the mycelium into the wood, a fact of fundamental importance when control measures are considered. He gave little information concerning the history of the disease in Illinois.

Older fruit growers interviewed by the writer all stated that blister canker has always been a serious problem in Ben Davis orchards. Since this variety was introduced into the state shortly after the Civil War, it is probable that the disease has been present in commercial orchards since that time. There is every reason to believe that it was to be found on several wild hosts, including wild crab and mountain ash in the neighborhood of the cultivated apple trees, previous to this time and only awaited the appearance of a susceptible variety to become destructive and generally distributed.

Blister canker is more prevalent and destructive in southern than in northern regions, but is found in all sections of the United States east of the Rocky mountains. It seems to be more destructive in the drier regions of the Great Plains than in the comparatively moist regions of the central and eastern states.

The fungus causing blister canker, *Nummularia discreta* (Schw.) Tul., has been found on a number of woody plants such as June berry (*Amelanchier canadensis*), mountain ash (*Sorbus americana* and *S. hybrida*), honey locust (*Gleditsia tricanthos*), white birch (*Betula alba*), white elm (*Ulmus americana*), redbud (*Cercis canadensis*), and magnolia (*Magnolia glauca*), as well as various species of Malus. It is reported to occur on pear, but has not been observed on this host in Illinois. It is common on apple and mountain ash in this state and has been observed on honey locust and elm. The disease is of economic importance only on the apple.

## LIFE HISTORY OF THE FUNGUS

In order to make clear the nature of the problem involved in the experimental work, it is necessary to present certain facts in regard to the life history and habits of this organism. No attempt is made to present all of the experimental work on which these facts are based. Where the writer has arrived at conclusions at variance with other investigators, a more detailed discussion is presented.

The fungus causing blister canker is an Ascomycete, *Nummularia discreta* (Schw.) Tul., and like most fungi of this group has two types of spores—conidia and ascospores. The conidia are produced in lenticular fruiting bodies, usually distributed over the new part of the canker. The outer covering of the lens-like structure breaks and the

edges roll back forming a star-shaped opening and exposing the honey-colored masses of conidia which are produced over the entire inner surface of the fruiting body (Fig. 3, *a*). Thus the rolled-back segments carry the spores into the open, where they can be easily scattered. While these spores may produce infections, their role in the life history of the fungus is not important and will be disregarded in the subsequent discussion.

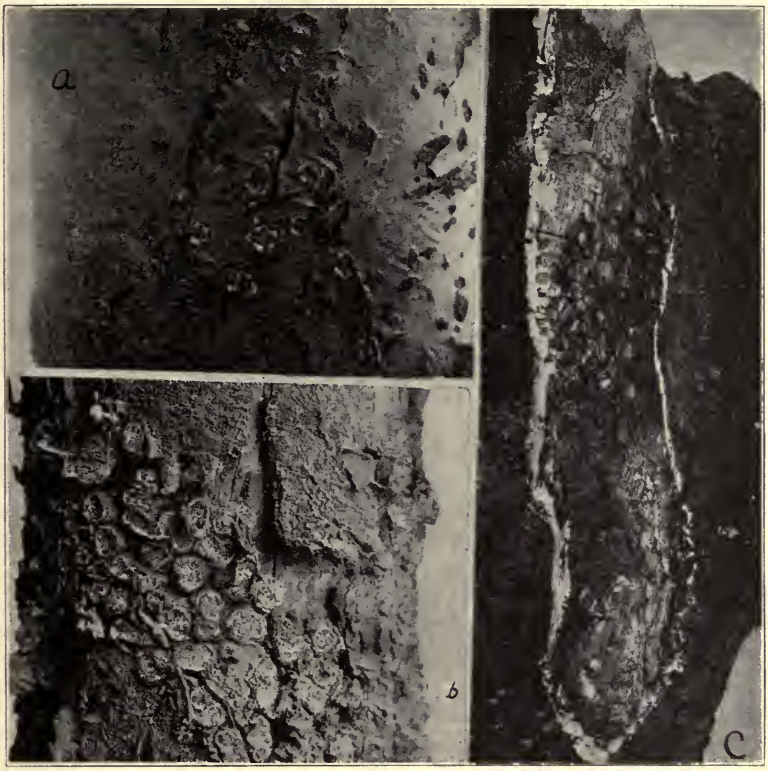


FIG. 3.—SPORE STAGES OF BLISTER CANKER

(*a*) "Blisters" with rolled-back edges exposing dust-colored masses of spores; (*b*) "nail heads" of perfect or winter stage. Mottled inner bark with black rings of sectioned blisters is shown at *c*.

The other spore stage is produced in the upper layer of the "nail heads" which characterize this disease.[1] (Fig. 3, *b*).

Both conidia and ascospores may be found in the same canker, but many cankers can be found with only the conidial stage, which is always produced first. That it takes at least two years to produce

[1]For a complete discussion of the symptoms and a description of the fungus, see Circular 258 of this Station, already referred to.

the ascospore stage is evident from numerous observations made on excised cankers and on new cankers over a period of years.

In the experimental orchard described later, about 100 cankers were excised in February and March, 1919. They were examined in October, 1919, and again in March, 1920. In late August, 1920, considerable advance of the cankered area had occurred but no fruiting bodies were found. In a neighboring orchard a number of cankered areas were marked as doubtful blister canker in March, 1919. These were examined several times during the summer of 1919. In July, 1920, a few of these had developed conidial fructification, but it was not until the late summer of 1920 that any ascospores were produced on these cankers. This point is important in the control of the disease. If a canker is excised one year, it may be safely left for two seasons without danger of ascospore production, altho as pointed out later, it is best to make annual surveys of the orchards.

The ascospores are ordinarily mature and discharging during the months of July, August, September, and October. Mature viable ascospores, however, may be found at any other time of the year, both in the perithecia and on the surface of the stromata. During periods when ascus production is not active, the perithecia are found crowded with ascospores freed from the asci. These evidently would not be discharged from the perithecium, but they might escape by the wearing away of the surface of the stromata, which occurs within a relatively short time after the greater portion of the ascospores are discharged. Discharge of ascospores takes place only when the bark is well soaked with water. Glass slides placed over the stromata on limbs in the orchard were examined at regular intervals during the summer of 1918 at Centralia, Illinois. It was found that very few ascospores were obtained except at intervals of two to three days following a heavy rain. Usually a day elapsed before discharge began, but occasionally it was initiated within twelve hours. Many mature perithecia were observed which did not discharge ascospores. The exact cause of this is not evident.

A continuous supply of ascospores for infection is provided in several ways: (1) not all ascospores mature at one time in a single perithecium; (2) not all perithecia are in the same stage of development even in a single stroma; (3) when discharged, not all ascospores are carried into the air or washed from the surface of the canker. In some cases all the discharged spores are prevented from reaching the outer air by a thin membrane covering the surface of the saucer-like stroma. The masses of purple spores may be seen, with the naked eye, heaped about the ostiole of the perithecium. Gloyer[1] has shown that on a single limb of mountain ash about a foot in length, on which there were 88 stromata, at least 350 million

[1]N. Y. (Geneva) Agr. Exp. Sta. Bul. 485, 39. 1921.

spores were exposed at one time. In attempting to wash these off, it was found that only a limited number could be washed off at one time, and that each washing over a period of weeks removed several hundred thousand additional spores. Thus, at all times, in an orchard where ascospores are being produced, there is an abundance of inoculum for infection.

### Spore Germination

While conidia germinate with difficulty and soon lose their viability, the ascospores germinate easily and retain their viability over at least a year. Ascospores on a limb left on an outside window ledge in October of 1918 germinated the following October. Stromata were collected from a pile of branches which had been left in an orchard for three years and from these, viable ascospores were readily obtained. The date when these ascospores were formed was uncertain, but it is probable that they were at least a year old before the limbs were cut. Stromata collected and placed in a vial showed viable ascospores eight months later.

### Dissemination of Disease

Observations and experiments over a period of ten years failed to give conclusive information concerning the methods of dissemination of the fungus, altho there seems every reason to believe that ordinary agents are operative. In the early part of these investigations, before the uncertainty of infection was realized, a number of experiments were tried to determine methods of dissemination. These resulted in failures, none of the inoculations, however made, producing infection.

Ants, bees, flies, woolly-bear caterpillars, and various undetermined insects were found to retain ascospores on their legs after walking across a number of damp stromata on which ascospores were abundant. A finger pressed against a mass of the ascospores retains thousands of these, and man is probably responsible for a general dissemination of the ascospores during the various operations about the orchard. The sawdust between the teeth of a pruning saw was cultured in 1919 and found to yield the organism, but the chance of infection by this means is probably far less important than by natural means.

Water carries enormous numbers of spores from cankers to lower limbs, but since infection in a tree is general by the time the cankers produce ascospores, this fact is of little importance. It is evident, from observations as to the initial infection, that many of these take place near the *top* of the tree or far out on the branches, and that spores that are washed down the limbs play no part in such infections. Shortly after the spores become massed on the surface of the stromata, they become dried, and later the whole surface weathers away. The spores actually discharged into the air, and those resting on the

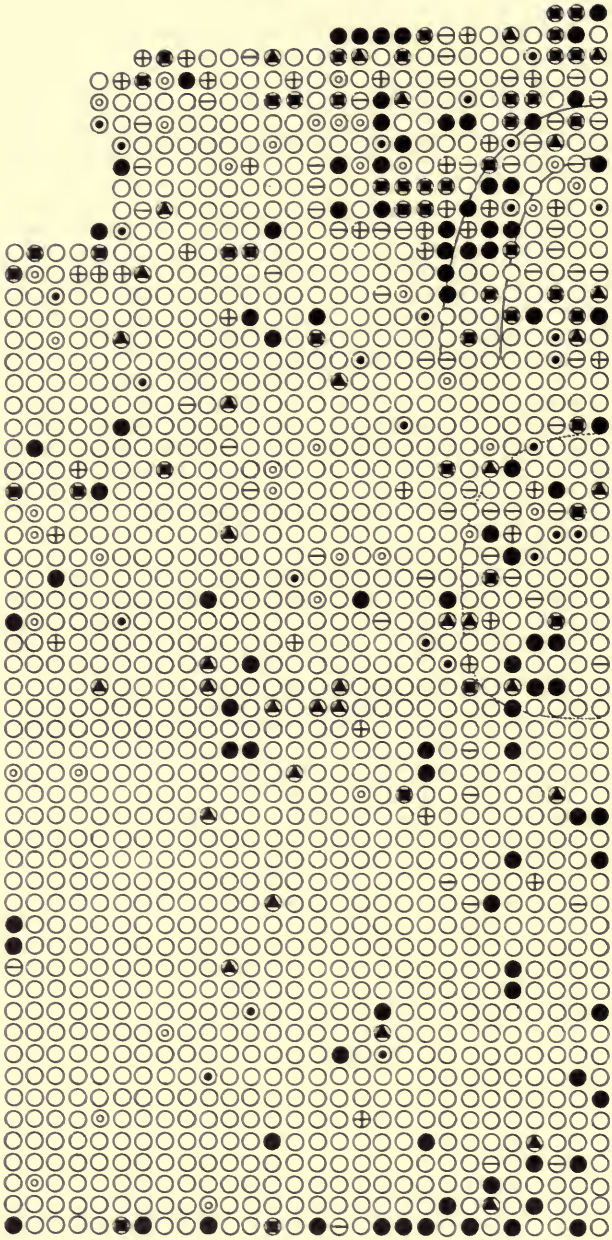

FIG. 4.—DIAGRAM OF EXPERIMENTAL ORCHARD, BARRY, ILLINOIS

○ Healthy tree ● Infected prior to 1921 ◉ 1921 ◉ 1922 ⊖ 1923 ⊕ 1924 ⊖ 1925 & 1926 ◎ 1927

surface of the weathering stromata, may be carried by air currents to other trees. That these spores rarely find conditions suitable for infection is evident from the comparatively slow spread of the disease.

The location of diseased trees in an orchard indicates that the chances of infection in the neighborhood of ascospore-producing cankers are greater than in remote portions of the same orchard. The grouping of diseased trees in the accompanying map (Fig. 4) of a typical orchard indicates this. On the other hand, the occasional scattered infections in this orchard can be explained only by assuming that the spores may be carried a considerable distance by air currents or other agents, but that the chances of infection are inversely proportional to the distance from the source of inoculum. Clustering of infections in an orchard may be explained in part by soil conditions, but this is by no means always true. Since the maximum number of spores are on the surface of the stromata during harvest time, it is probable that the pickers play some part in disseminating the spores. At this time, also, broken limbs resulting from the weight of the fruit and carelessness of pickers are so general that chances of infection are exceptionally good.

### How Inoculation and Infection Occur

Infection takes place only on the "wood" of the tree, never on the fruit, leaves, or current season's growth. Repeated attempts by the writer to produce infection by inoculations on the unwounded surface, in the bark, cambium, and young xylem have always resulted in failure. This has also been the experience of other investigators, so that it may be stated with certainty that natural infection is always in the xylem or wood of the tree. Cooper[1] has produced artificial infection with both conidia and ascospores in the cambium of older limbs, but the percentages of success were low. He shows further that in two-, three-, and four-year-old wood the percentage of infection is much greater. The numerous experiments of Gloyer and Cooper indicate that infection takes place only where the spores are protected from drying and where continuous moist conditions prevail. Such conditions were produced by boring holes in the limbs and, after inoculation, covering the wounds with grafting wax, or with cloth coated with paraffin or grafting wax or both. While under these conditions infection with conidia could be easily produced in wood, it is evident that natural conditions are not simulated.

## INFECTION EXPERIMENTS

Attempts were made to determine whether infection could occur on new and old pruning wounds where no protection was afforded.

[1]Nebr. Agr. Exp. Sta. Res. Bul. 12, 16. 1917.

These experiments were made under conditions favoring infection by the fungus, but owing to the fact that trees of a susceptible variety were not available in quantity, only a limited number of inoculations were possible. At Barry in 1920, in August and again in September, inoculations were made on 34 trees of nineteen-year-old Ben Davis in a block of this variety which up to that date had not showed evidence of blister canker either in the appearance of cankers or of slime-flux from the wounds. The owner had pruned the trees a few years before, removing a number of large limbs. In 1919 a few more limbs had been cut off, and a few days previous to the first series of inoculations, ten limbs varying in age from two to six years were removed. No attempt was made to sterilize the wounds, since any disinfectant applied to the surface would have soaked into the cut surface and thus vitiated the experiment.

The inoculum was secured by crushing in rain water a large number of stromata containing perithecia from which ascospores were shooting. A soft brush was used to distribute the spores over the surface of the wounds. The wounds were then covered with several layers of paper towels soaked in water. Since the weather was cloudy at the time of inoculation, these coverings remained damp for two days and were then removed. The total number of inoculations was 132, ten of which were made on recently cut wounds and the remainder on wounds of at least one year of age. Very little cracking of the wood was observed in these wounds. Where it did occur, efforts were made to force the inoculum from the brush into the cracks.

These inoculated trees were watched from 1920 until 1927, since it was realized that infections may take several years to appear externally. Of the 34 trees thus inoculated, only one showed evidence of canker in later years. In 1924 one tree developed a canker near the top. The limb was removed and the infected wood traced. No evidence of any connection with the inoculations could be found. In 1926 four limbs were removed where inoculations had been made on branches from these limbs, and cuts were made across the limbs near the points of inoculation. No evidence of infection could be found.

These infection experiments were too few in number and made over too limited a time to draw any safe conclusions, but they do indicate that infection thru even large pruning wounds is not common. One could surmise this from observation, since thousands of pruning wounds made in this same orchard and exposed to infection over a period of years, resulted in comparatively few diseased trees.

Another series of inoculations was made on four twelve-year-old Ben Davis trees at Urbana in 1918. The results of these experiments bear out those obtained by Gloyer and Cooper and need not be given in detail. Forty wounds made by inserting ascospores, conidia, and pure cultures of the fungus under the bark, resulted in no infection.

These wounds were all cut out the following spring and no growth of the fungus into the surrounding tissue was observed. Ascospores placed on an old pruning wound covered with waxed paper and then with grafting wax gave a positive infection, but this did not become evident until two years later (1921). Seven attempts to infect newly cut stubs in the same manner resulted in failures. A broken stub in the top of the tree was also inoculated and covered. Infection occurred in this case, but there was no external evidence until 1921, when a canker appeared around a wound two feet below the point of inoculation. The infection was traced in the wood to the point of inoculation.

At various times during the past ten years additional infection experiments were carried out, but the results were negative and gave no additional light on the conditions favorable to infection except that they indicated the difficulty of producing infection by superficial inoculations.

Attempts were made to produce natural infection by sawing first thru a cankered branch and then thru a healthy branch or stub. The number of such trials was limited, owing to the fact that the work had to be done in a commercial orchard. Seventy-four such cuts were made where the limbs used were alive and from three to seven years old. Eighteen were made on limbs that had died from various causes, mostly from being shaded by higher branches. Active cankers were selected, and after the diseased limb was removed, sawdust was moistened and placed between the teeth of the saw. Three of the trees so inoculated developed cankers within the next six years, but in no case could the infected area be traced to the limbs removed altho one was so generally diseased as to render the point of primary infection doubtful.

In the face of these generally negative results it would appear that statements to the effect that large pruning wounds result in infection are to be discredited. However, where conditions are particularly favorable, as when there is cracking and subsequent inoculation followed by closing of cracks thru a prolonged wet period during the critical time for infection, it is not at all improbable that such wounds may be responsible for infection.

## OBSERVATIONS AND EXPERIMENTS ON THE ORIGIN OF CANKERS

From 1917 to 1928 a study was made of blister canker in the Ben Davis orchards of this state. Surveys were made of four large orchards, including a total of over 10,000 trees. From 1919 to 1928 more detailed observations were made of the orchard in which the experimental work on canker control was carried out. During the course of this work each one of nearly 1,600 trees had to be carefully

examined and, where cankered, the extent of the cankered area had to be determined. These extensive field observations gave an opportunity to study the conditions under which natural infection occurs. When the study was initiated, it was thought that the external canker indicated the point of infection, but it was soon realized that this is by no means always true. In fact, large cankers are rarely formed about the primary point of infection.

In making these examinations, it was necessary to have a method for distinguishing between infected and uninfected wood. Cooper[1] made sections of the infected wood and stained the fungus to determine its course. This method was considered too laborious for the extensive investigations planned. It was found possible to secure cultures of the blister canker fungus from small blocks of the infected wood, and this method was used until the writer had become so familiar with the characteristics of diseased wood that he felt justified in discontinuing the cultural method.

At first a large number of cultures were made from diseased wood on agar plates. The agar used was a prune agar with lactic acid added to discourage bacterial growth. The mycelium of *Nummularia discreta* in this medium is characteristic, and it was possible to make determinations with ease where the wood was sufficiently isolated from external sources of contamination. From 10 to 25 pieces of wood could be placed on a single plate and identified by numbers on the underside of the plate. At first the ends of the outgrowing mycelial threads were transferred to tubes to secure pure cultures, but it was found that this was not necessary, and as soon as the characteristic growth occurred in the plate, the results were recorded and the cultures discarded.

Not all brown areas in the wood of an apple tree are due to *Nummularia discreta*, even where these areas are irregular in outline or have the characteristic "streaks" described by Gloyer. In a recent study of brown streaks originating at pruning wounds, made in cooperation with Dr. W. A. Ruth, of this Station, it was found that such streaks may extend for several feet into the wood of the tree and have all the characteristics of fungus or bacterial invasions. Such extensions of brown areas in the Ben Davis are not so common as in other varieties, but they do occur and they may be somewhat irregular in cross-section, thus resembling Nummularia infected areas. When such doubtful cases were encountered, the cultural method was resorted to even after familiarity with infections made diagnosis reasonably certain. It is interesting to note, in connection with the cultural work, that few fungi belonging to other species were isolated. The most common one was the black rot organism *Physalospora cydoniae*, which is not supposed to invade the wood of the apple tree.

[1] *Loc. cit.*, pp. 24-25.

Some of the results of numerous isolations are here presented to illustrate the manner in which the fungus grows in the wood. Fig. 5 represents a number of cross-sections of a limb on which there was no evident canker. The closest canker occurred on a limb arising on the main trunk of the tree two feet above the base of this limb. When the limb was removed, it was evident that the wood was diseased and cultures were made at various points along the limb. All the cultures were positive when the wood was taken from the portion showing brown rot as illustrated by the dark areas in the various sections in Fig. 5. Attempts were then made to determine the distribution of the fungus in the wood which was not discolored. When made alongside the brown streaks, either on the radial or tangential face, no cultures could be obtained, but longitudinally cultures were secured a half-inch beyond the last trace of the "streak." Cultures beyond one inch were negative and in numerous other experiments cultures were rarely obtained beyond the last visible trace of the discolored wood.

In other experiments an attempt was made to determine whether a tree having *no evident canker* but showing slime-flux on a cut limb was infected. Four limbs cut at intervals along the trunk showed the discolored areas in the older wood. These all yielded positive results when cultured. In this case no evidence of the point of primary infection was found, but it might have originated on a limb which had been removed a year or so previous.

Another tree showing slime-flux was examined in the same manner. The cuts made in this case showed evidence of discolored wood, but it was light brown and the outline in cross-section was even. Negative results were obtained in all the cultures. The presence of slime-flux is not a certain indication of blister canker, as evidenced by this and similar experiments and observations.

These illustrations indicate the reliability of the methods used in determining the origin of infection in the numerous observations made in the orchards. It was not always possible to determine the point of infection, since the trees would have had to be severely crippled by numerous cuts but, when possible, sufficient cuts were made to determine the extent of the diseased tissues. Only those trees were used on which not more than one or two cankers were found and those in such a position as to allow the limbs to be cut off without seriously injuring the trees. In a number of cases entire trees badly cankered were cut down and limbs sawed off at various points to determine the extent of the diseased area. In every such case it was found that the disease was generally distributed throuout the larger branches and usually extended to near the top of the topmost branch. In some cases the three- and four-year-old branches showed no evidence of diseased tissues.

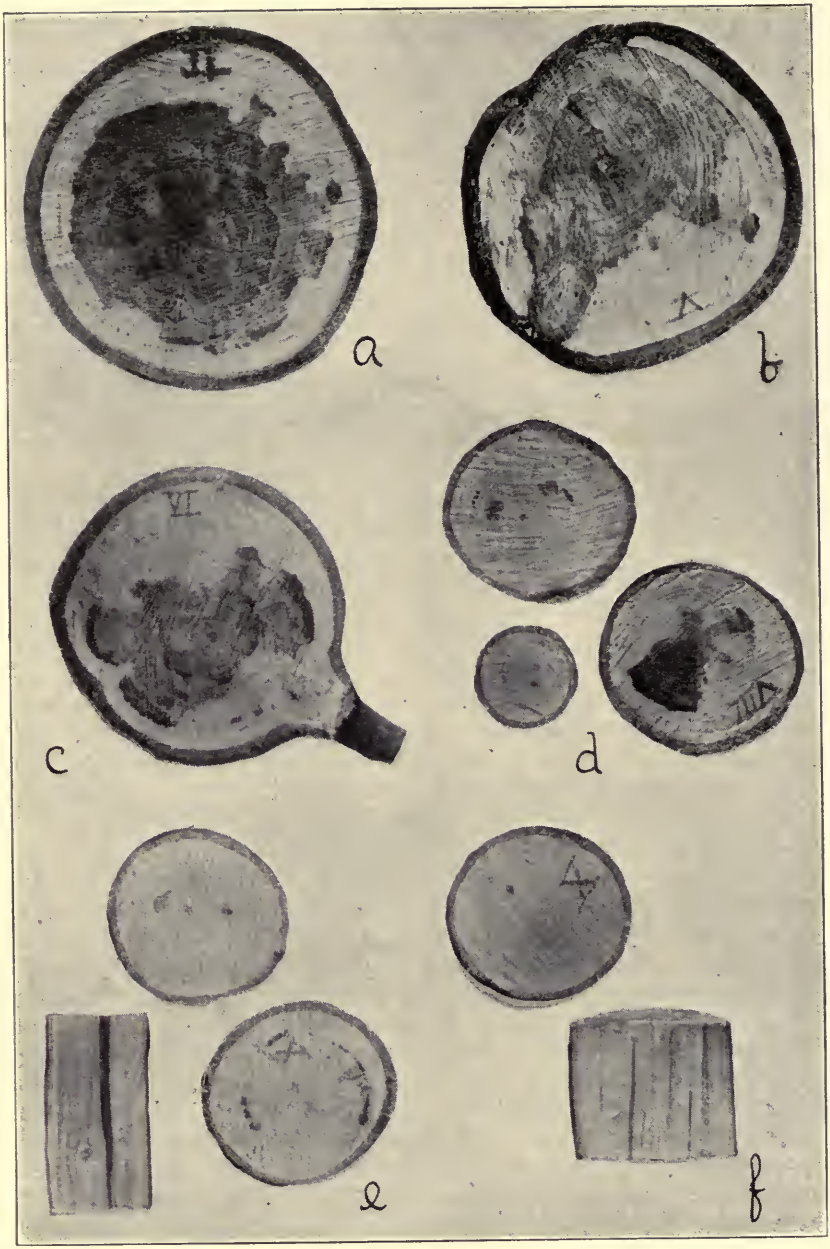


FIG. 5.—CROSS- AND LONGI-SECTIONS OF A LIMB HAVING NO CANKER BUT TAKEN FROM A DISEASED TREE

As a result of all observations made during this ten-year period, the writer has come to the conclusion that the majority of primary infections in the Ben Davis variety originate in broken branches where a ragged stub is left which retains moisture for several days. Such broken branches are very numerous, especially near the tops of the trees (Fig. 6). These infections are favored by the fact that in older Ben Davis trees growth is slow in the tops and numbers of comparatively old but small branches are produced in this region.

FIG. 6.—CANKER DEVELOPING AROUND A STUB RESULTING FROM A BROKEN BRANCH

The arrow points to the probable origin of the canker but not necessarily to the point of infection.

These usually bear heavily and are easily broken both by the weight of the fruit and by pickers. A pocket is formed in the main branch exposing xylem several years old, and if the broken branch remains on the tree an especially favorable wound for the collection and retention of water is produced (Fig. 7). In other cases the break is several inches from the main limb and a jagged end is left in the cracks in which water may be retained for some time (Fig. 8). Spores sifting down into such pockets find a favorable situation for germination and infection (Fig. 8).

When a large canker is seen about a pruning wound, the natural inference is that such a canker originates at this wound. On this basis the majority of cankers in an orchard would be ascribed to large pruning wounds but, as shown later, cankers are produced in most

cases by *outward* growth of the mycelium from the heartwood or older xylem of the tree. There is no question but that some pruning wounds serve as infection courts, especially where they are made in such a way as to collect water or where large cracks develop in the wood. However, the number of primary infections taking place in such wounds is far below that occurring in broken branches. This is especially true when the cut is made in such a way as to allow rapid run-off of surface water.

FIG. 7.—TYPE OF STUB WHERE INFECTION OCCURS

A broken limb leaves a pocket well adapted for holding spores in a moist condition. In this case a canker has just started to develop about the wounded area.

Cooper states that wounds about the base of the tree and on the roots serve as infection courts. This is certainly an exceptional method under Illinois conditions. In the first place, the wounds made are rarely more than superficial and, secondly, in the older orchards in which blister canker is most common, cultivation is confined to the areas between the rows and rarely extends to within three feet of the trunks of the trees. In only a few instances has the writer found evidences of canker on the trunk or base of the tree except where the tree was infected thruout the heartwood and the origin of the infection consequently was questionable.

Infection seems to be rare on trees less than fifteen years old. This may be due in part to the fact that the fungus does not readily infect rapidly growing tissues but probably is due mainly to the absence of broken branches and exposed wood surfaces. Small cuts heal rapidly and show little cracking in a rapidly growing tree. Infection has never been traced to pruning wounds made by removing water sprouts.

## Development in Host Tissues

Cooper[1] gives a very accurate account of the growth of the mycelium in the wood tissues of young trees where artificial infections were made. He shows that in general the growth of the fungus is much more rapid in older trees, that in a tree of any age the growth is more rapid in the older wood, and that the mycelium grows downward much more rapidly than upward. He further shows that lateral and radial growth is very slow as compared with longitudinal growth.

Additional facts resulting from observations need to be recorded in order to explain some phases of the problem of the appearance of secondary cankers. By "secondary cankers" is meant those which develop from the outward growth of the fungus elsewhere than at the point of the original infection. In order to obtain a clear picture of the progress of the fungus in the tree, a hypothetical case will be presented, the accompanying sketch of a tree in longisection serving as an illustration (Fig. 9).

FIG. 8.—TYPE OF WOUND IN WHICH MOST INFECTION OCCURS

This illustrates a condition similar to the one in Fig. 7 but shows a deeply cracked side branch suitable for infection. The dark line indicates the limit of the cankered area.

At *a* a heavily laden branch had broken from the main limb in such a manner as to leave at notch which extended into four-year-old wood of the main branch. Spores lodging in this splintered notch found conditions favorable for germination and the germ tubes grew into the wood. As stated previ-

[1] *Loc. cit.* pp. 28-35.

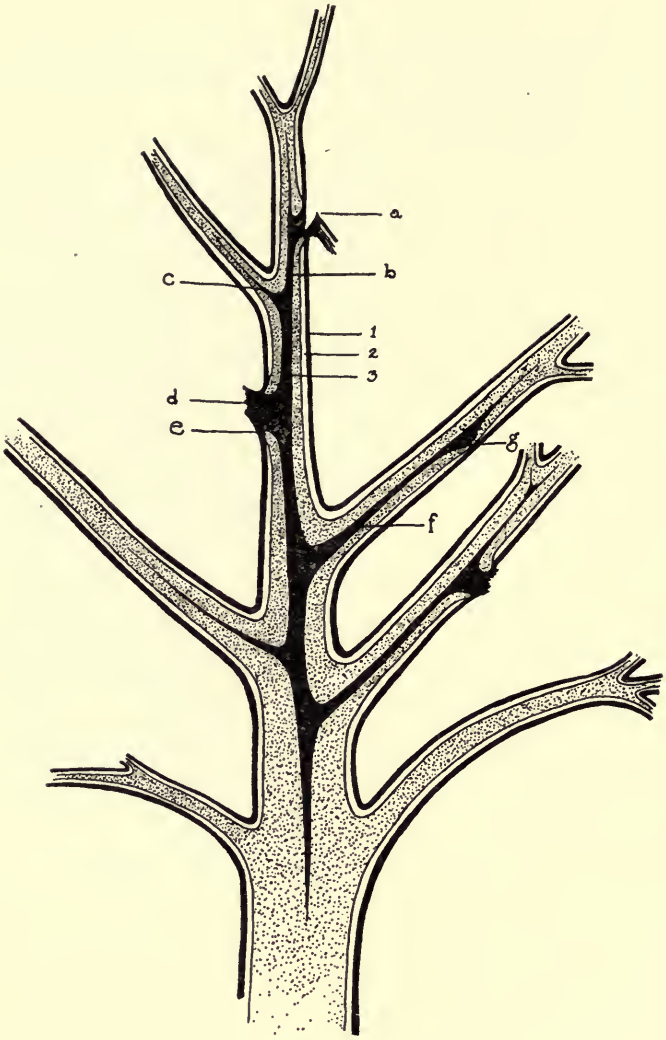


FIG. 9.—WOOD INVASION BY NUMMULARIA

Diagrammatic representation of progress of invasion. (1) Bark, (2) sapwood, (3) heartwood. Explanation of the letters is given in the text.

ously, the growth of the fungus is much more rapid up or down than laterally or radially; consequently for a while the fungus bores thru the wood and grows down the main stem, following that portion of the xylem in which it first entered. Probably because of the more suc-

culent growth of the wood near the top of the tree (*b*), the fungus does not come to the surface of the wound in this region and there is no evidence of canker at the point of infection for several years. In some cases where the growth of the top parts of the tree have been decidedly slowed down on account of cultural conditions, the fungus may develop a canker within a year or so after infection. As the fungus grows down the woody part of the tree, it gradually invades more and more of the drier tissues of the xylem, but for the most part it progresses along a definite path, that is, in one segment of the woody cylinder. The downward growth may continue for a period of several years or may progress several feet in a year, depending upon factors not easily determined. The moisture content of the wood is probably one determining factor, but no definite experiments along this line have been conducted.

After the fungus has invaded the main stem, it grows out into the lateral branches (*c*) but since the ring of active, growing tissue is usually thick and unbroken about the heartwood on these limbs, the growth of the fungus is confined to the inner wood and does not form external cankers until later.

At *d* a limb has been removed and the bark at *e* below the wound is thin, with the dry xylem comparatively close to the surface. Under such conditions the fungus grows out thru the heartwood of the stub and rapidly invades the bark around *e*. At the same time the growth of the fungus continues downward and invades a lateral branch, as at *f*. At *g* on this branch the heartwood is close to the bark as a result of starvation of the limb at this point. The fungus makes another exit here and a canker is formed. Cankers at *e* and *g* are evident sooner than at *a*. Thus the cankers that are first observed in a survey of an orchard usually are not near the point of infection but may be located in a distant part of the tree.

## Cause of External Fruiting

Most fungi have a period of development during which there is an "inherent urge" to fruit. This fructation period is seasonal with some fungi, but in other cases is determined by nutritional conditions. Wood-inhabiting fungi usually fruit only when the fruiting bodies can be exposed so that the spores may be disseminated. It is this tendency on the part of *Nummularia discreta* which accounts for the appearance of the cankers and the production of external fruiting bodies. But the fungus does not grow thru the uninjured, growing, succulent wood and bark. Rather it grows down or up, until the mycelium reaches a point where a wound has occurred, such as a large pruning wound, or where the growth of the wood has been so slow as to make a thin barrier between the comparatively dry wood and the outer bark. Where there is a large pruning wound, a

dry area exists about the center of this wound and the fungus spreads outward, finally invading the bark and even the rather succulent tissues of the callus which develops about such a wound.

A good illustration of the direct penetration of the mycelium thru the thin annual layers of slow-growing wood is seen in Fig. 5, *b*. When this limb was removed, no evidence of canker was observed.

Fig. 10.—Type of Tree Especially Subject to Outbreaks of Canker

Bare, upright branches are quite likely to develop large cankers because of the small amount of sapwood present.

but later a small sunken spot was noticed along the lower side of the limb. When the sections represented in this figure were made, the reason for this sunken spot was evident. At *b*, on the underside, the annual rings indicate a very slow growth, and it was at this point that the fungus grew outward and would have produced a canker within a few weeks after the limb was removed. This explains the appearance in the orchard of large cankers on the side of a perfectly healthy limb from which not even water sprouts have been removed. This condition is common in the orchard where the experimental work described later was carried out. Because of faulty pruning a number of trees in this orchard had, in place of a main central stem, four or five large upright branches of about equal size (Fig. 10). Frequently no side branches were to be found on these main limbs for a distance of three or four feet. An examination of cross-sections of such limbs showed that they had made a very rapid growth for five

or six years but later, owing to competition for water and food, the growth had slowed down especially in those regions where the side branches were infrequent. It was on such branches that large cankers would appear with alarming suddenness while no wounds were to be found and no cankers had been observed previous to these outbreaks.

It is important to emphasize this method of canker formation since it is quite different from the usual conception of the origin of cankers. In the case of fire blight, for example, the infection takes place in a water sprout or a blossom. The organism invades the outer bark and spreads downward until it enters the larger parent limb where, by its spread thru the bark tissues, it produces a canker. The black rot fungus (*Physalospora cydoniae*) and others act in the same manner, that is, the canker develops from the *outside*, works inward, and is confined to the bark.

On the other hand, *Nummularia discreta* acts much like the wood-rotting fungi of the Basidiomycetes, in that the wood is first invaded, rotted for the nourishment of the vegetative part of the fungus, and finally the mycelial strands work their way to the exterior to produce the fruiting bodies. The exact factors involved in the outward migration of the mycelium are not known, but it is evident that there must be a stimulant which reacts on the fungus in some definite manner.

In its vegetative condition *Nummularia discreta* grows best in wood of a definite water content, seemingly preferring the intermediate rings of wood growth rather than the drier heartwood or the more succulent outer xylem. This may be due in part to nutritional causes altho the fungus grows readily in both heartwood and young xylem in vitro. It is certain that in its early vegetative condition the tendency is for the fungus to grow away from the air and from the drier wood of the wound on which infection occurs and toward the heartwood.

In the foregoing discussion, emphasis has been placed on the wood-inhabiting character of this fungus, as contrasted with other canker-producing fungi, for the reason that control measures must be decidedly different when dealing with a fungus of this type.

## INFLUENCE OF ENVIRONMENT AND TYPE OF GROWTH ON PREVALENCE OF BLISTER CANKER

Blister canker occurs on trees growing in all types of soil. A large Ben Davis orchard on black silt loam showed approximately the same percentage of blister canker as one of the same age on gray silt loam on tight clay. The disease is prevalent in the orchards of Calhoun county, where rich loess soil is the predominating type. It is also prevalent in the yellow silt loams of the Ozark regions in southern Illinois. The soil of the experimental orchard at Barry is largely yellow silt loam.

Neither does soil reaction influence the prevalence of the disease. Orchards have been observed with an abundance of the disease where the soil has been limed on account of legume cover crops and is consequently alkaline. Very acid soils are common in orchards in the central section of the state where the disease is general.

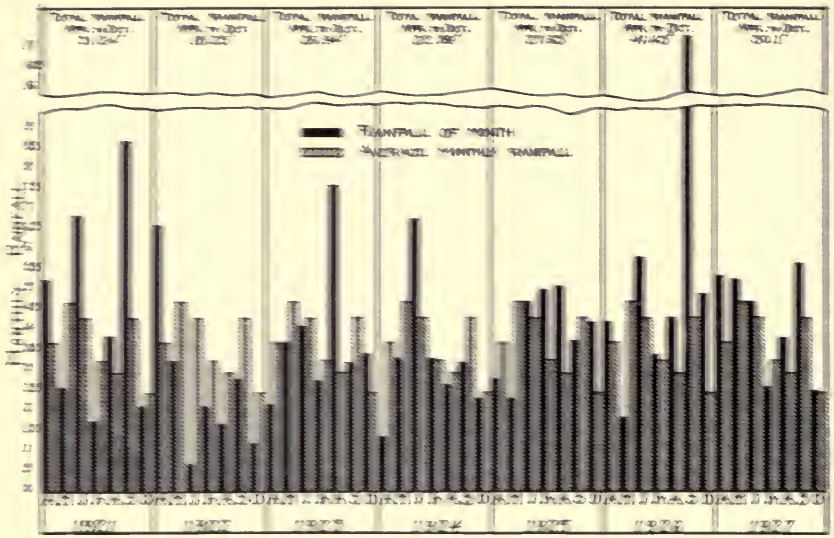


Fig. III.—Monthly Rainfall at Gainesville, 1925–1927. From Lemn. to October Inclusive

The solid black shows the rainfall in inches for the current year, while the diagonal lines indicate the average for the month over a period of years. The difference between them shows the excess or deficiency for that month.

Topography is also of minor importance except as it relates to water drainage. A detailed study of the location of the diseased trees in three orchards where the topography was varied showed that this factor did not influence the relative abundance of diseased trees. Cankered trees can be found on a south, north, east, or west slope.

Seasonal rainfall is usually important in the relative prevalence of plant diseases, especially those which manifest themselves shortly after infection, as is the case with foliage and fruit diseases. Where infection is not immediately evident, the problem becomes more complicated and the evidence of increase is not so easy to obtain. The appearance of more or of fewer cankers in a season is not necessarily correlated with the number of infections for seasons which have been explained. That dry weather influences the outbreak of cankers has been the opinion expressed a number of times by growers of wide

experience. Glover[1] attempts to correlate certain series of consecutive dry seasons with serious general outbreaks of the disease. He believes that the lowering of the water table increases the prevalence of the disease, while short drouths have little influence.

An attempt was made to correlate rainfall, during the months of April to October inclusive, with the prevalence of the disease in the experimental orchard. The records of the weather station at Griggsville, 18 miles east of Barry, were used. The rainfall of each year from 1921 to 1927 inclusive, for the months of April to October, are given in Fig. 11 together with the normal rainfall for those months in the same region. A prolonged, severe drouth occurred in 1922 during the months of May to October inclusive. While 1924 shows less than the normal rainfall, the rain was evenly distributed and no drouth condition occurred. The season of 1926 shows a very high total rainfall on account of very heavy rains in September, when 16.83 inches of rain occurred, while the normal rainfall for that month is 4.36 inches.

The table on page 84 shows that slightly more new cankers appeared in the dry seasons of 1922 and 1924 than in 1923 and 1926 when the rainfall was above normal. In 1927, following three seasons of rainfall above normal, the largest number of new cankers was recorded, with the exception of 1921. Observations on the rate of growth of the existing cankers showed that there were no great differences from year to year altho there was a decided variation in different trees. Casual observations in other orchards indicated that more cankers could be found in a season following a year when the total rainfall was less than normal, but the records of the experimental orchard failed to substantiate this theory.

Soil drainage seems to play some part in the prevalence and severity of the disease. Orchards on well-drained soil suffer less than those where the drainage is poor. The orchards of Clay and Richland counties are notorious for the amount of blister canker. Many of these orchards are situated on level land with a tight clay subsoil and both surface and subsoil drainage is poor.

In the experimental orchard the question of the influence of drainage was carefully studied, since this seemed to be the only soil factor that promised definite results. The manager of the orchard stated that the first cankered trees he had noticed were near an old race track. The outline of this track is still evident in the orchard. In the northeast corner of the orchard a pronounced embankment was made in order to build up a low area. There is a sharp slope to the northwest in this part of the orchard. In the area outlined on the map (page 62) the water is retained over long periods of time by the embankment of the race track. It will be observed that practically all the trees in this area were cankered or became so during the seven years of the

[1] N. Y. (Geneva) Agr. Exp. Sta. Bul. 485, 13-16. 1921.

experiment. On the outer edge of this embankment, toward the northwest, a number of smaller "pockets" occur, evidently representing areas where the soil was obtained for the embankment. That this prevalence of canker is not due to impoverished soil is proved by the fact that these trees are as large as, or larger than, the trees in the remainder of the orchard.

FIG. 12.—TYPE OF TREE ON WHICH CANKER IS RARELY EVIDENT

The scaffold limbs are fairly well distributed. Compare this with the tree in Fig. 10.

Another area where soil drainage is poor is represented by the dotted outline on the map on the east side of the orchard between Trees 20 to 34 and Rows 1 to 7. Here again the trees show an unusual amount of canker. The trees in this area are exceptionally large, with a tendency to have three or four very long upright main limbs as represented by Fig. 10.

On the other hand, the trees in the southwest portion of this orchard are on a knoll which affords excellent surface drainage. Trees here have made less growth than those in the north and east parts of the orchard but they produce heavy crops and show very little blister canker.

The type of growth of individual trees is the result of pruning practices and soil factors. The experimental orchard has been pruned

under the direction of the same manager since it was planted, and it is safe to assume that the same pruning practices have been followed thruout the orchard. The differences in the type of tree growth in various areas of the orchard may, therefore, be ascribed largely to differences in soil fertility. In general, the trees in the northeast section, where the soil is fertile, have shown a tendency to develop three or four long upright main branches with a limited number of laterals (Fig. 10), while the trees in the southwest portion, where clay soil predominates, have a single central leader with large laterals spaced rather close together (Fig. 12). Trees of the first type are usually larger than those of the second, altho the owner states that the smaller trees in the southwest portion outyield those of the other type. A study of these two types revealed the fact that most of the cankers occurred in trees having a number of large upright branches. The prevalence of cankers in trees of this type is not necessarily related to the vigor of the tree, since some very vigorous trees of the central-leader type are to be found in the area where cankered trees of the other type are common.

The reason for the abundance of cankers and their severity in trees of the upright type may be explained in part by the fact that, first, the fruit-laden branches break off very easily in this type, thus giving chances for infection, and second, the sapwood on these upright branches is very thin as compared with that on a central leader, and there must exist some competition for water between the various branches of about equal size.

## EXPERIMENTS ON CONTROL OF BLISTER CANKER[1]

The object of this phase of the experimental work was to determine whether it is possible to reduce the number of diseased trees in an orchard in which excision has been practiced below the number in an orchard in which excision has not been practiced. The assumption that such a reduction might result was based on the knowledge that, where blister canker occurs, the diseased trees are found in groups, indicating a slow spread from a center of infection. This statement does not imply that infection is *always* over short distances, since it is common to find isolated diseased trees in an orchard. However, a glance at the map (Fig. 4) shown on page 62 is sufficient to demonstrate that groups of diseased trees do occur about a center of infection; also, that isolated diseased trees are not numerous as compared with those in colonies.

Since infection results mainly from ascospore inoculations, the elimination of all stromata before ascospore production was essential

[1]For recommendations for control of blister canker in young as well as older orchards, see Circular 258 of this Station, already referred to.

for the success of the experiment. For this reason it was impossible to leave check trees in the same orchard where the experiments were performed. This was recognized as a weakness in the experimental work, but since neighboring orchards of the same age, on the same type of soil, managed by the same man were available, this weakness was not considered a serious one.

## Plan of the Experiment

The orchard selected for the experiments on control of blister canker is located one and one-half miles southwest of Barry, Illinois. It consists of a solid block of 1,520 trees of Ben Davis. The orchard was planted in 1898, so that at the beginning of the experiments in 1919 the trees were twenty-one years old. They had made a good growth and were in excellent condition at the time the experiments were started. Very little pruning had been attempted until the year 1915-16, when a number of the lower branches and some higher in the trees were cut out. The upper ones were removed following breaking caused by an unusually heavy crop of fruit. The branches removed were usually quite large, that is, exceeding one inch in diameter. The manager labored under a mistaken idea that the branches should be sawed, leaving a stub twice the length of the diameter of the branch removed. This resulted in leaving numerous stubs and much exposed wood surface.

This orchard was selected for the following reasons: (1) the canker had not established itself to such an extent that control measures were deemed impractical; (2) the trees were of the age at which this variety usually begins to develop canker; (3) an orchard of the same age and variety and under the same management bordered the experimental block.

## Methods Used

Some fundamental facts in regard to the control work were recognized before this experiment was started, and these need to be emphasized at this time: (1) Not all infected trees had evident cankers, so that 100-percent elimination of cankers the first year would not mean that cankers appearing the next year on new trees were the result of infection following the excision of the cankers. (2) A few new infections could be expected from outside sources, especially from two neighboring orchards used as controls. (3) The excision of cankers did not imply elimination of the disease in the tree nor a guarantee that new cankered wood would not appear outside the excised cankered area. However, during the first three years, after cutting out a canker the wound and tools were sterilized and the wood was painted later in the season by the manager. After the first three years no attempt was made to sterilize either the wounds or the tools, since the futility of such procedure was realized. The wounds were always

cut back to healthy bark because it was observed early in the experiments that in some cases callus is formed about the edge of the wound and may continue healthy for several years, thus prolonging the life of the limb. Also, the insects commonly found in the dead bark along the edge of the cankers were absent. At first, shellac was used to cover the wounds before painting, but this was discontinued on account of the extra labor, altho it is still recommended. Since it was felt that the success of this plan of blister canker control must be made practical, all operations not essential to the successful reduction of the canker were eliminated.

A series of preliminary experiments on wound treatment were tried in 1919, partly with the hope that a substance could be found which would prevent the extension of the cankered area over a period of years and thus reduce the labor. Furthermore, these experiments were designed to indicate whether or not standard methods of wound treatment would prevent the ultimate extension of the cankers.

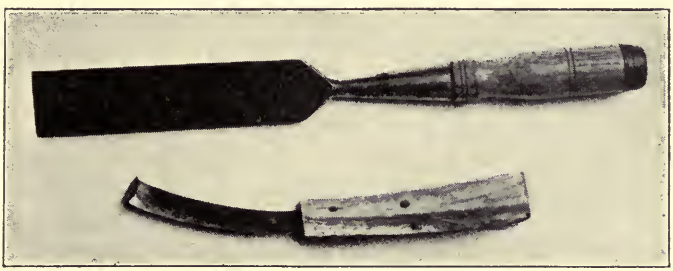

FIG. 13.—TWO TOOLS USEFUL IN CUTTING OUT CANKERS, A FARRIER'S KNIFE AND A CHISEL

Other experiments were designed to answer the question: Can blister canker be entirely eliminated from a tree by removing cankered limbs in an early stage? Certain trees were selected which had single cankers near the top of the tree or far out on side branches, and the entire limb was removed or the cut was made far enough below the canker to be reasonably certain that all diseased wood was removed.

## Tools Employed for Excision

At first a rather elaborate set of tools was carried to operate on the trees, but after two years' experience these were reduced to two instruments, a farrier's knife and a good pruning saw. Limbs too large to be cut with a pruning saw were marked and were later removed by workmen using a crosscut saw. The farrier's knife is the most useful instrument for this work, but it should be of a very good quality steel and should have the curved end ground down until a right-angled bend is secured rather than a hook (see Fig. 13). A

small drawknife is useful and permits rapid work, but if the ferrier's knife is kept sharp, it serves the same purpose.

At the start a map of the orchard was prepared and a number of blue line prints from a Van Dyke negative were made (Fig. 4). The trees were given numbers and all diseased trees were marked after each survey. The map was carried during the survey, together with the notes of the previous year. Since the number of cankers and their general location were given in these notes, it was possible to locate any new cankers on old diseased trees as well as on newly diseased trees.

## Excision of Cankers

Experience is necessary in locating cankers that have not fruited. It was found that the mottled bark was the only reliable indication of canker in the absence of fruiting bodies. In an old orchard where numerous other cankers are to be found, the ability to distinguish blister canker is essential to the success of this program of control. The experience of the writer has been that most orchardists never become skilled enough to locate all cankers, but since the program of control allows excision after the formation of stromata, the importance of earlier location of the cankers is minimized. As a rule, the orchardist should employ someone who has had a long experience in this line of work since an unskilled worker rarely locates more than half the cankers. In the orchard adjoining the experimental orchard, the author followed workmen who had helped in the first year's work, and found that approximately 50 percent of the cankers had been overlooked.

No attempt was made to destroy the fruiting bodies removed from the canker during the first year's operations. It was realized that there was a possibility of these discharging spores while lying on the ground, but there seemed to be no practical way of catching all the excised bark since it was very brittle and would fly in all directions when cut. Since the cankers were cleaned out the second year and in subsequent years before the fruiting bodies were formed, the chance of infection from the removed materials existed only during the first year. A preliminary treatment of the cankers with a strong fungicide, such as copper sulfate, to kill the spores would probably have reduced the danger of reinfection, but some preliminary experiments in 1918 indicated that this method was unreliable as an orchard practice. An effort was made to see that no particles of bark remained in the limb crotches below where the cankers were excised. Aside from this, no precautions were taken.

The first operation in excising the cankers was to cut out all the dead area down to the wood. This can be done rapidly by using the farrier's knife much as one would use a drawknife. After all the dead bark was removed, a stripe was cut about the edge of the canker

so that healthy bark completely surrounded the wound. The entire wound was then sponged with a solution of mercuric chlorid and mercuric cyanid with some glycerin added.[1] Except between 1919 and 1921, when the treatment of cankers was under investigation, the owner, later in the year, painted all pruning wounds, and the canker wounds were covered at that time.

FIG. 14.—RENEWAL OF BEARING AREA ON CANKERED TREE WITH MOST OF MAIN STEM REMOVED

If properly pruned, the vigorous new branches developed on such trees will yield paying crops before the entire tree is killed by the disease.

No limb was removed by excision which could be saved for another crop. It took only a few minutes more to clean out a large canker than it did to saw off a limb, and the crop of the following year might be well worth saving. When the limb was within an inch or so of being girdled, no attempt was made to save it, since under such conditions it will die before the crop of the following year is matured. Another reason for saving limbs is that the removal of large limbs exposes others to serious sun scald (Fig. 14). A limb which is destined to die within two or three seasons should have a number of the smaller

[1]This solution was used after 1923. It consisted of a solution of 1 to 500 mercuric chlorid and 1 to 500 mercuric cyanid, the solvent being equal parts of glycerin and water. This solution has less glycerin in it than the California formula for fire blight control and is much more satisfactory for blister canker work. Previous to 1923 a 1 to 500 mercuric chlorid solution was used.

branches removed in order to allow the branches which it shades to become gradually exposed to the sun.

Excision of cankers was started in February, 1919. At this time 76 trees, or exactly 5 percent, were found to be diseased. A number of trees were infected which showed no external evidence of canker, since the owner had recently cut out a number of cankered branches. For this reason, the estimation of percentage increase was not attempted until the season of 1921.

## Wound Treatment Experiments

Following the winter excision of cankers all the wounds, with the exception of 15, were treated with various materials to determine whether any method of preventing or delaying the advance of the diseased area in the bark adjacent to the excised area could be devised.

The first series was painted with a refined, thick gas tar which had to be heated in order to be applied satisfactorily with a brush.

The second series was painted with a pure white-lead paint thinned with unboiled linseed oil.

The third series received a treatment of grafting wax around the exposed edge and a subsequent painting with white lead.

The fourth series received a thick shellac treatment followed a few hours later with a covering of gas tar which was allowed to cover the wood but not the edge of the bark.

The fifth series was treated with asphaltum and varnolene as recommended by the Ohio Station in 1912 (Circular 126).

The sixth series was not treated and served as a check.

Observations made on these trees during the next three years showed that none of the treatments was satisfactory in delaying the spread of the cankered area and consequently no further treatment was given the wounds other than sterilizing, as previously described. A coat of paint was applied each year by the owner as a general

BULGING CANKER INFECTION IN EXPERIMENTAL ORCHARD OF 1,320 BEN DAVIS TREES AT BARRY, ILLINOIS: 1921-1927

| | Number | Proportion | Annual increase |
|---|---|---|---|
| | | *percent.* | *percent.* |
| Total trees infected prior to 1921 | 94 | 6.18 | ..... |
| Total newly infected trees | | | |
| In 1921 | 48 | 9.34 | 3.16 |
| In 1922 | 34 | 11.58 | 2.24 |
| In 1923 | 27 | 13.36 | 1.78 |
| In 1924 | 37 | 15.79 | 2.43 |
| In 1925 | 30 | 17.76 | 1.97 |
| In 1926[1] | 29 | 19.67 | 1.91 |
| In 1927 | 38 | 22.17 | 2.50 |

[1] No survey was made in 1925. The new infections of the 1926 survey were divided between the two years.

treatment for all wounds. The only advantage of any treatment of wounds, so far as blister canker is concerned, is that borers and woolly aphids are discouraged from working in the bark at the edge of the cankered area. Any good paint or gas tar answers this purpose.

## Results of Excision Experiments

Beginning with 1921, and with the exception of 1925, an annual survey was made each autumn after the leaves had fallen. In 1925

FIG. 15.—A CASE OF SUCCESSFUL TREE SURGERY

This tree had the main stem removed in 1919. The photograph was taken in 1929. The tree will bear several more profitable crops even tho it is badly diseased.

the pressure of other work prevented the completion of the survey. In 1927 the last survey was made, and at this time an attempt was made to secure accurate records on neighboring orchards which served as checks on the experiments. The accompanying table (page 84) summarizes the results obtained.

Prior to 1921, 94 trees or 6.18 percent were evidently cankered. At the end of seven years 337 trees, or 22.17 percent, were diseased. Thus there was an average annual percentage increase of about 2.28. The percentage of newly infected trees, it will be observed from the table, increased at a rather uniform rate, and the percentage difference varied little from year to year despite the fact that the number of diseased trees in the orchard was much greater in the later years of the investigations. This indicates that since the increase in total diseased trees did not increase the chance of infection, the inoculum

must have come from sources outside the orchard, or that the trees that later showed evidence of cankers had been infected previous to the beginning of the experiments. This latter assumption is in line with inoculation experiments reported earlier, where the cankers did not develop until four years after the inoculations. It is probable that

FIG. 16.—CHARACTERISTIC SECONDARY GROWTH ON A DEHORNED TREE

If properly trained, such diseased trees may produce abundant crops. The water sprouts should have been thinned and headed back at the proper time.

a majority of the cankered trees found during the last three or four years were the result of infections from sources outside the orchard.

## Results in Check Orchards

As stated earlier, it was thought best not to leave checks in the orchard where the experiments were carried out on account of the possibility of infection spreading from these check trees.

Across the road from the experimental orchard were 40 acres of Ben Davis and Grimes Golden planted at the same time and under the same management as the experimental block. In the spring of 1919 this orchard was surveyed with the intention of using it for blister canker experiments, but so few cankers were found that it was thought best not to use it. In 1920 there was certainly less than 1 percent of blister canker in evidence in this orchard. About 1921 some cankered

trees were observed by the manager, and he began to cut out all limbs showing advanced canker but did not cut out the incipient cankers. This orchard, therefore, was receiving better care than the average Illinois orchard, so far as canker was concerned, and was selected as a check on the experimental block.

On November 1, 1927, a portion of this orchard was surveyed for blister canker. There is a probability that not all trees that had become infected were observed in this survey, since, as stated above, the manager of the orchard had systematically removed cankered limbs each year since 1921, and thus some trees infected at this time would not yet show canker. Seven hundred fourteen trees were examined. Of these 459 were healthy, to all appearances, and 255 showed disease. Thus the check orchard, starting with less than 1 per cent of diseased trees in 1919, showed 35.7 percent diseased in 1927, while the experimental orchard, with 5 percent of diseased trees in 1919, showed only 22.17 percent in 1927. Furthermore the 1927 figure for the check orchard is a very conservative measure of the amount of infection that had actually taken place in that orchard subsequent to 1919, for the reasons given above.

Another and perhaps more accurate check was furnished by a small group of 60 trees belonging to the experimental orchard but separated by a small stream. These trees had been surveyed with the original orchard and the cankers removed in 1919 with the exception of one tree which was to have been cut down but which was not removed as directed. In this block of 60 trees 4 were diseased in 1919, or about the same percentage as found in the rest of the experimental orchard at this time. In subsequent years no survey or other work was done on these trees, and on account of their isolation the manager did not give them much care so far as cutting out cankered limbs was concerned. In 1927 a survey was made of these trees and it was found that 36 of the 60 trees, or 60 percent, had blister canker, as compared with 22.17 percent in the experimental block.

A comparison of the first check orchard of 714 trees with that of the experimental orchard shows that in eight years there had been an average annual increase of 4.46 percent in the number of diseased trees in the check orchard, as contrasted with an annual increase of 2.65 percent for seven years during which the experimental orchard was observed. In the second check orchard for eight years the annual increase averaged 6.67 percent. This was about what would be expected in an orchard where no attempt was made to cut out the cankered limbs or excise the cankers.

In two large commercial orchards in other parts of the state where an attempt had been made by the owners to cut out all cankered limbs but where rigid excision of cankers had not been practiced, surveys made in 1917 and 1918 showed 35 to 38 percent of the trees

cankered. These trees were of the same age as the experimental orchard at the close of the experimental work.

From these facts we may conclude that the careful excision of cankers over a period of years reduced the number of cankered trees below what would be expected, and consequently increased the annual crop and prolonged the useful bearing age of the orchard. An increase of five or ten years in the life of an orchard at the time of maximum production will pay many fold for the labor involved in excising cankers.

### Experimental Work on Removal of Cankered Limbs

During the course of the experimental work at Barry a number of limbs were observed which, when externally examined, showed evidence of having been infected a year or two previously. Six of these were selected for further observation. Four were in the Ben Davis block, while two were in an adjoining block of Maiden Blush where only a few trees had become infected. The infected limbs were removed and cuts made in the stubs until no further evidence of the brown streaks could be observed. The cut surfaces were then sterilized and covered with grafting wax after being shellaced. Three of the trees were treated in 1919, two in 1921, and one in 1923. No further evidence of the disease was found in five of the trees during the subsequent years. One of the two trees treated in 1921 developed canker in 1924, but this occurred on a large limb on the opposite side of the tree, and no connection between the first cankered limb and the new area of infection could be found.

Thus, it appears that where it is possible to find the origin of the infection early enough in its development the disease can be entirely eradicated, but from a practical standpoint this fact has little significance since the discovery of infection at a sufficiently early period is quite difficult.

## SUMMARY AND CONCLUSIONS

1. Blister canker causes serious economic losses in Illinois orchards owing to the high percentage of Ben Davis and Gano trees in the older orchards.

2. The loss results from decrease in bearing wood and from the early death of the trees.

3. The fungus is a wound parasite and will not infect thru unbroken bark. It is primarily a wood-invading organism.

4. Infection takes place thru exposure of wood but rarely if ever in small pruning wounds.

5. Large pruning wounds are not ordinarily subject to infection, especially if the exposed surface is smooth.

6. Most infections in the orchard occur in wounds produced by broken limbs, especially in the tops of the trees.

7. Cankers about wounds do not necessarily indicate that the wound was the original seat of infection.

8. Cankers ordinarily appear where the relatively dry xylem is close to the surface of the limb.

9. Wood invasion is extensive before the cankers appear on the surface.

10. Physical factors, such as types of soil, site of orchard, and amount of rainfall, do not seem to influence the relative prevalence of canker.

11. Drainage seems to have some influence in the prevalence of canker in that poorly drained areas have a larger percentage of diseased trees than those well drained.

12. Type of tree growth is an important factor in that trees having a uniform growth thruout their development are less likely to develop cankers than those making a rapid growth at one period followed by restricted growth at another.

13. Cutting off diseased limbs, practiced by many orchardists, does not eliminate the disease from the tree.

14. Excision of cankers is effective in reducing the number of newly infected trees if annual excisions are made and if no cankers are overlooked.

15. Proper attention to pruning and care of wounds in the early life of the orchard will assure the owner of an orchard trees that are free from this disease.

16. The only satisfactory method of control in infected orchards is careful and consistent elimination of spore-bearing cankers.

## RECOMMENDATIONS FOR CONTROL

Details concerning control of blister canker are given in Circular 258 of this Station. Following is a brief summary of these, including some modifications made necessary by more recent experiments:

1. Varieties susceptible to blister canker, such as Ben Davis and Gano, should be avoided.

2. If Ben Davis is planted, highly resistant varieties, such as Grimes, York Imperial, Oldenberg, or Winesap, should be planted in the adjacent rows rather than moderately susceptible varieties, such as Delicious, Yellow Transparent, or Jonathan. In general, slow-growing varieties with "bushy" types of growth are less susceptible than rapid-growing varieties with upright growth.

3. If new orchards of susceptible varieties are planted, they at least should not be planted near older orchards in which blister canker is prevalent.

4. Young trees should be pruned and trained early in their development so as to avoid the need for heavy pruning later.

5. Susceptible varieties should not be stimulated to make excessive growth at any one period in their development. Soil treatments should be regulated so as to secure an even growth during the life of the orchard.

6. Good drainage should be assured before the orchard is planted, but if the orchard is already established, care should be taken to secure adequate underground drainage in all parts of the orchard.

7. Frequent inspections of the trees should be made and all suspicious cankers carefully examined. If they are blister cankers, efforts should be made to cut out the limbs on which they occur, or the trees, if young, should be destroyed and replaced.

8. When the trees begin bearing, the branches broken by an overload of fruit or by the carelessness of pickers should receive special attention during pruning operations the following winter. The pruners should be instructed as to the proper method of treating such wounds, as given in the preceding discussion of the subject.

9. If the disease has been established in an orchard, the annual excision of cankers as outlined in this bulletin and in Circular 258 of this Station should be followed. Success depends upon complete elimination of spore-bearing surfaces. A few cankers overlooked during a season may result in numerous new infections.